

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

- 1 1. (Currently Amended) A linear method for performing head
2 motion estimation from facial feature data, the method comprising
3 the steps of:
4 obtaining a first facial image and detecting a head in said
5 first image;
6 detecting position of ~~not more than~~ only four points P of said
7 first facial image where $P = \{p_1, p_2, p_3, p_4\}$, and $p_k = (x_k, y_k)$;
8 obtaining a second facial image and detecting a head in said
9 second image;
10 detecting position of ~~not more than~~ only four points P' of
11 said ~~first~~ second facial image where $P' = \{p'_1, p'_2, p'_3, p'_4\}$ and $p'_k = (x'_k, y'_k)$;
12 and
13 determining the motion of the head represented by a rotation
14 matrix R and translation vector T using said points P and P' .

1 2. (Currently Amended) The linear method of claim 1, wherein
2 | said only four points P of said first facial image and said only
3 | four points P' of said second facial image include locations of
4 | outer corners of each eye and mouth of each respective first and
5 | second facial images.

1 3. (Original) The linear method of claim 1, wherein said
2 | head motion estimation is governed according to:

3 $P'_i = RP_i + T$, where $R = \begin{bmatrix} r_1^T \\ r_2^T \\ r_3^T \end{bmatrix} = [r_{ij}]_{3 \times 3}$ and $T = [T_1 \ T_2 \ T_3]^T$ represent camera

4 | rotation and translation respectively, said head pose estimation
5 | being a specific instance of head motion estimation.

1 4. (Currently amended) A linear method for performing head
2 | motion estimation from facial feature data, the method comprising
3 | the steps of:

4 obtaining a first facial image and detecting a head in said
5 | first image;

6 detecting position of four points P of said first facial image
7 | where $P = \{p_1, p_2, p_3, p_4\}$, and $p_k = (x_k, y_k)$;

8 obtaining a second facial image and detecting a head in said
9 | second image;

detecting position of four points P' of said ~~first~~ second facial image where $P' = \{p'_1, p'_2, p'_3, p'_4\}$ and $p'_k = (x'_k, y'_k)$; and,

determining the motion of the head represented by a rotation matrix R and translation vector T using said points P and P' ,

wherein said head motion estimation is governed according to:

$$P'_i = RP_i + T, \text{ where } R = \begin{bmatrix} r_1^T \\ r_2^T \\ r_3^T \end{bmatrix} = [r_{ij}]_{3 \times 3} \text{ and } T = [T_1 \ T_2 \ T_3]^T \text{ represent camera}$$

rotation and translation respectively, said head pose estimation being a specific instance of head motion estimation, and

wherein said head motion estimation is governed according to said rotation matrix R , said method further comprising the steps of:

determining rotation matrix R that maps points P_k to F_k for characterizing a head pose, said points F_1, F_2, F_3, F_4 representing three-dimensional (3-D) coordinates of the respective four points of a reference, frontal view of said facial image, and P_k is the three-dimensional (3-D) coordinates of an arbitrary point where

$P_i = [X_i \ Y_i \ Z_i]^T$, said mapping governed according to the relation:

$$\begin{aligned} R(P_2 - P_1) &\propto [1 \ 0 \ 0]^T \\ R(P_6 - P_5) &\propto [0 \ 1 \ 0]^T \end{aligned}$$

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30 wherein P_5 and P_6 are midpoints of respective line segments
 31 connecting points P_1P_2 and P_3P_4 and, line segment connecting points
 32 P_1P_2 is orthogonal to a line segment connecting points P_5P_6 , and
 33 \propto indicates a proportionality factor.

1 5. (Original) The linear method of claim 4, wherein
 2 components r_1 , r_2 and r_3 are computed as:

$$\begin{aligned} & r_2^T(P_2 - P_1) = 0 \\ & r_3^T(P_2 - P_1) = 0 \\ 3 \quad & r_1^T(P_6 - P_5) = 0 \\ & r_3^T(P_6 - P_5) = 0 \end{aligned}$$

1 6. (Original) The linear method of claim 5, wherein
 2 components r_1 , r_2 and r_3 are computed as:

$$\begin{aligned} 3 \quad & r_3 = (P_6 - P_5) \times (P_2 - P_1), \\ & r_2 = r_3 \times (P_2 - P_1) \\ 4 \quad & r_1 = r_2 \times r_3 \end{aligned}$$

1 7. (Original) The linear method of claim 4, wherein

$$\begin{bmatrix} P_1^T & 0^T & 0^T & 1 & 0 & 0 \\ 0^T & P_1^T & 0^T & 0 & 1 & 0 \\ 0^T & 0^T & P_1^T & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} r_1 \\ r_2 \\ r_3 \\ T \end{bmatrix} = P_1^T$$

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3 each point pair yielding 3 equations, whereby at least four
4 point pairs are necessary to linearly solve for said rotation and
5 translation.

1 8. (Original) The linear method of claim 7, further
2 comprising the step of: decomposing said rotation matrix R using
3 Singular Value Decomposition (SVD) to obtain a form $R = USV^T$.

1 9. (Original) The linear method of claim 7, further
2 comprising the step of computing a new rotation matrix according to
3 $R = UV^T$.

1 10. (Original) A linear method for performing head motion
2 estimation from facial feature data, the method comprising the
3 steps of:
4 obtaining image position of four points P_k of a facial image;
5 determining a rotation matrix R that maps points P_k to F_k for
6 characterizing a head pose, said points F_1, F_2, F_3, F_4 representing
7 three-dimensional (3-D) coordinates of the respective four points
8 of a reference, frontal view of said facial image, and P_k is the

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9 three-dimensional (3-D) coordinates of an arbitrary point where

10 $P_i = [X_i \ Y_i \ Z_i]^T$, said mapping governed according to the relation:

11

$$R(P_2 - P_1) \propto [1 \ 0 \ 0]^T$$

12

$$R(P_6 - P_5) \propto [0 \ 1 \ 0]^T$$

13

14 wherein P_5 and P_6 are midpoints of respective line segments
15 connecting points P_1P_2 and P_3P_4 and, line segment connecting points
16 P_1P_2 is orthogonal to a line segment connecting points P_5P_6 , and
17 \propto indicates a proportionality factor.

1 11. (Original) The linear method of claim 10, wherein
2 components r_1 , r_2 and r_3 are computed as:

$$r_2^T(P_2 - P_1) = 0$$

3 $r_3^T(P_2 - P_1) = 0$

$$r_1^T(P_6 - P_5) = 0$$

$$r_3^T(P_6 - P_5) = 0$$

1 12. (Original) The linear method of claim 11, wherein
2 components r_1 , r_2 and r_3 are computed as:

3 $r_3 = (P_6 - P_5) \times (P_2 - P_1),$

$$r_2 = r_3 \times (P_2 - P_1)$$

4 $r_1 = r_2 \times r_3$

1 13. (Original) The linear method of claim 12, wherein a
2 motion of head points is represented according to $P'_i = RP_i + T$

$$R = \begin{bmatrix} r_1^T \\ r_2^T \\ r_3^T \end{bmatrix} = [r_{ij}]_{3 \times 3}$$

3 where $T = [T_1 \ T_2 \ T_3]^T$ represents image rotation,

4 represents translation, and P'_i denotes a 3-D image position of four
5 points P_k of another facial image

1 14. (Original) The linear method of claim 13, wherein

$$2 \quad \begin{bmatrix} P_i^T & 0^T & 0^T & 1 & 0 & 0 \\ 0^T & P_i^T & 0^T & 0 & 1 & 0 \\ 0^T & 0^T & P_i^T & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} r_1 \\ r_2 \\ r_3 \\ T \end{bmatrix} = P'_i,$$

3 each point pair yielding 3 equations, whereby at least four
4 point pairs are necessary to linearly solve for said rotation and
5 translation.

1 15. (Original) The linear method of claim 14, further
2 comprising the step of: decomposing said rotation matrix R using
3 Singular Value Decomposition (SVD) to obtain a form $R = USV^T$.

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1 16. (Original) The linear method of claim 15, further
2 comprising the step of computing a new rotation matrix according to
3 $R = UV^T$.

1 17. (Currently Amended) A program storage device readable by
2 machine, tangible embodying a program of instructions executable by
3 the machine to perform method steps for performing head motion
4 estimation from facial feature data, the method comprising the
5 steps of:

6 obtaining a first facial image and detecting a head in said
7 first image;

8 detecting position of ~~not more than~~ only four points P of said
9 first facial image where $P = \{p_1, p_2, p_3, p_4\}$, and $p_k = (x_k, y_k)$;

10 obtaining a second facial image and detecting a head in said
11 second image;

12 detecting position of ~~not more than~~ only four points P' of
13 said ~~first~~ second facial image where $P' = \{p'_1, p'_2, p'_3, p'_4\}$ and $p'_k = (x'_k, y'_k)$;
14 and,

15 determining the motion of the head represented by a rotation
16 matrix R and translation vector T using said points P and P'.

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